Alberta
ENVIRONMENT CONSERVATION AUTHORITY

SELENIUM, ANIMAL HEALTH AND SOUR GAS PLANTS

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and
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January, 1973

STAFF REPORT

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FOREWORD

A submission regarding an indirect effect of sulphur emissions was heard at the Public Hearings of the Environment Conservation Authority on the Environmental Effects of the Operation of Sulphur Extraction Gas Plants which were held in October, 1972. It discussed the occurrence of selenium deficiency diseases in domestic animals.

In western Alberta, particularly in the environs of the Sulphur Extraction Gas Plants from Pincher Creek to as far north as Whitecourt, there has been a relatively high incidence of selenium deficiency diseases in domestic animals. Selenium is essential as a nutrient for animals and lack of a proper supply can lead to severe debilitation of the animal. Many farmers and some veterinarians in western Alberta attribute the rise in the incidence of White Muscle Disease to emissions from sour gas plants.

It is known that elements which are similar can replace each other in chemical reactions both within and outside living systems. The element most similar to sulphur is selenium. In view of this the Authority commissioned the present staff report on the suggested relationship of selenium deficiency diseases to ambient sulphur concentrations in the area. Information relevant to this subject is also to be found in a report from the Canadian Forestry Service on the effects of sulphur dioxide on vegetation, referred to in the bibliography of this report.

Environment Conservation Authority

1. SELENIUM IN SOILS

Selenium is a naturally occurring trace element in soils. Its concentration in the various soil types is intimately associated with the original geologic formation and its subsequent history to the present. (Figure 1 outlines the boundaries of the soil zones in Alberta.) Among these soil zones, not only is the selenium content variable but also the chemical forms in which it is held differ. Thus, it is quite possible for a soil to contain a large amount of selenium in a form which does not permit its incorporation into the plant tissue. This is a rather general feature of soils and may be extended to all plant nutrients. For example, a particular soil may be high in sulphate sulphur and yet be considered deficient in the sense that such sulphur may be as water-insoluble calcium sulphate, magnesium or aluminum sulphate and thus unavailable to vegetation.

Analytical techniques are known which can determine the amount of soluble sulphate in the soil (Carson *et al.*, 1972). However, unlike sulphur, the soluble selenium content of soils cannot be determined, as all present techniques determine the total selenium content. Therefore, when one speaks of selenium-deficient soils, the phrase implies that the above-ground portion of crops grown on such soils contains concentrations of selenium insufficient to meet the nutritional requirements of animals or humans dependent upon that crop as their sole food supply. A comparable definition may be extended to soils having toxic levels of selenium.

2. SELENIUM IN VEGETATION

Crop plants in which we are interested do not seem to require selenium as an essential growth element; rather the plants act as carriers for selenium, transmitting it to the animal. Certain plant species do require selenium as an essential nutrient, but they are not believed to exist in Alberta. There are plants, however, which take up much more selenium than others, these have been termed "selenium accumulators". A certain milk vetch species (Astragalus sp.) growing in Alberta may contain a selenium level so high as to be toxic to livestock. This plant is only consumed if an area has been over-grazed or there is no other food available. While there have been cases of selenium toxicity in livestock in the Manyberries area of southern Alberta, they have been few in number.

Selenium enters a plant via the root system as a soluble selenite or selenate. While the selenium is not required as a nutrient in forage crops, it is incorporated into the plant proteins. Associated with the proteins, it is apparently present mainly as seleno-amino acids: selenocystine, selenocysteine, selenomethionine, and selenocystathionine. A fraction of the total uptake remains as selenite or selenate.

Two studies of selenium levels in Alberta forage exist. D.R. Walker, Canada Department of Agriculture, Lacombe, has been measuring forage response to sulphur fertilization for a number of years. Recently this work has been expanded to include plant selenium measurements (Walker, 1971a). D.L. Massey and P.J. Martin, Alberta Department of Agriculture, have classified the soils of Alberta on the basis of selenium concentration measurements obtained from barley grains grown in the various Alberta soil zones (Massey, Martin, 1972a).

Walker (1971a) measured the selenium content of 262 samples of alfalfa, red clover, alsike clover, timothy and bromegrass grown at 59 soil-year sites. The data from this study are given in Table 1. Forty of the soils were classified as sulphur deficient, as determined by legume yield response to fertilization. Selenium levels in the above species decreased by a statistically significant amount only where fertilization had increased plant yield. This Walker attributes to "dilution", or a relatively constant selenium uptake as forage yield increased. It is evident from this study that alfalfa takes up more selenium than other species and that practically all of the samples had selenium levels that would be considered as deficient for animal nutrition, if it is accepted that 30-200 parts per billion of selenium in a diet is essential to animal vitality (Massey, Martin, 1972b). Any level below 100 parts per billion is considered by animal nutritionists to be potentially deficient.

In 1972, Massey (Massey, Martin, 1972a) analyzed 394 samples of barley grain from all areas of Alberta. The grain had been submitted by farmers for routine testing during the period 1970-72. There was obviously less control of sample history than in the study by Walker. The data for this study are given in Table 2 and the corresponding source soil areas are indicated in Figure 1. It should be noted that throughout the province there are areas where forage will contain less than an average of 100 parts per billion selenium, but that the most prominent selenium-deficient area is the northern two-thirds and west central part of the province. In these areas over one-half of the samples tested contained less than 100 parts per billion selenium.

The areas outlined in Figure 1 delineate the soil zones of the province. These soils vary in their organic matter and those elements essential to plant growth. Consequently the availability of selenium is also expected to be a function of soil type. As an example, Grey Wooded soil, zone 8, is extensively leached and usually deficient in nitrogen, phosphorus, organic matter, and often sulphur. It is within this zone, particularly west of Highway 2, between Edmonton and Calgary, that selenium/vitamin E responsive diseases have been most often observed. Although the scope of this study (Massey, 1972) is limited to one grain type, there would certainly appear to be a correlation between selenium level in the forage and the type of soil. On the basis of the data there obviously appear to be many areas of the province where selenium deficiency could create a nutritional problem.

Apparently there are two ways in which selenium uptake by a plant can be depressed when sulphur fertilizer is added to the soil. Walker (1971a) attributed the decrease in selenium concentration mainly to "dilution", that is, a relatively constant selenium uptake as forage yield increased. This dilution effect has also been reported elsewhere (Davies and Watkinson, 1966) to be the principal factor which decreases the selenium concentration. A direct inhibitory effect of sulphate ions replacing selenium was also reported by Hurd-Karrer (1938) and Ravikovitch and Margolin (1959). Such an effect is to be expected due to the chemical similarity of the two elements. It has been demonstrated that selenium can replace sulphur in plant amino acid synthesis, for to quote Treshow (1970):

> "Cases have been reported of one element substituting for another. ...selenium can replace sulfur in certain amino acids such as selenomethionine or selenocystine.
>
> Nutrient ion interaction may affect the absorption of elements from the soil, so that a chemically similar ion may be absorbed rather than the essential element. In this way arsenate may interfere with phosphate absorption, selenate with sulfate..."

Such a similar substitution of sulphur for selenium would be expected when sulphur is present in a large excess. The net result of either "dilution" or "direct inhibition", or a combination of both, would be to decrease the selenium concentration.

3. SELENIUM FROM SOUR GAS PLANTS

Selenium and sulphur occupy the same family grouping in the periodic table of elements and as such may interchange with each other in compound formation. On this basis, if selenium was present in any quantity during the time hydrogen sulphide was being formed, then the presence of selenium compounds in sour natural gases might be expected. Selenium is not normally analysed for in sour gases, but one special investigation has been carried out recently. In this analysis of stack gases, stockpiled sulphur, surface run-off water and river water at a gas plant near Pincher Creek and one west of Innisfail the selenium levels were found to be just at the limit of detection (2-6 parts per billion). It is not expected that these quantities of selenium are sufficient to be beneficial to selenium-deficient soils or to lead to concentrations in vegetation that would be considered toxic to animals.

4. SELENIUM IN ANIMAL NUTRITION

4.1 General

The importance of selenium in animal and human nutrition has been appreciated only within the last few years. Human diets are sufficiently varied that selenium deficiency diseases are a rare occurrence, but the same cannot be stated for livestock. Moreover, selenium deficiency in animals is not confined to Alberta, but has been diagnosed in other parts of Canada, the United States, and at least fourteen other countries. There are numerous diseases attributed to an insufficient level of selenium in an animal's diet and it is common practice to refer to them as selenium responsive diseases.

White Muscle Disease (WMD), Nutritional Muscular Dystrophy (NMD), or Nutritional Myopathy (NM) (myopathy meaning any muscle disease) are terms applied to the afflictions under discussion. The common name, WHITE MUSCLE DISEASE, is given because of a bleaching of affected muscles which may, in extreme cases, lead to a distinct clarification in skeletal muscle. Both skeletal and heart muscles are commonly affected; however, these are only gross manifestations of the disease, most changes are microscopic and not easily observed. Clinically the condition appears in calves

up to three to four months of age and is characterized by stiffness, muscular weakness, and rapid death if the heart muscles are severely affected; stillbirths are common if the parent is not supplied with sufficient selenium. It must be noted that while the main interest in Alberta is directed to cattle, similar symptoms occur in swine, horses, chickens, and turkeys. In swine, the common disease name is Mulberry Heart Disease.

Selenium is ingested by the animal in any of a number of compounds. As mentioned in Section 2, forage contains selenocystine, selenocysteine, selenomethionine and selenocystathionine, as well as selenite and selenate. As much as 70% of the selenium in alfalfa may be bound as selenomethionine (Muth, 1967). The selenites or selenates can be reduced by the animal micro-organisms to seleno-amino acids and incorporated into proteins. Selenium not only remains incorporated in the animal system but it is also reduced to the elemental form in the gastrointestinal tract of ruminants (Muth, 1967). An examination of ruminant excretions showed the following: of the total selenium excreted, 40% was in the urine as selenate and selenite, 40% was in the fecal matter as elemental selenium, and 20% was in the feces as organic selenium.

Although a certain minimum amount of selenium is essential in animal and human nutrition, its metabolic function is uncertain. It has been suggested that selenium possibly acts as a carrier for vitamin E, serves as an antioxidant, is essential in the synthesis or activation of some enzymes involved in decarboxylation, and takes part in the production or activation of lipose (any of a group of enzymes that aid in digestion). MacDonald (1972a) lists some 25 medical conditions in which selenium and vitamin E have been incriminated as causal agents, either individually or together.

The standard practice by veterinarians in treating WMD is to inject the affected animal with a solution of sodium selenite-vitamin E. Preventative measures are taken by adding the selenite-vitamin E mixture to mineral salt licks.

5. SELENIUM-SULPHUR RELATIONSHIP

The effect of sulphur on the selenium content of vegetation is well understood, as noted in Section 2 and in a review article by Allaway (1970). The influence of sulphur on selenium in the animal is not that well defined, however, as a survey of the literature has indicated.

Whanger (1970) discussed the interaction between sulphur and selenium in relation to rumen micro-organisms, ruminants and nonruminants. Studies have indicated that rumen micro-organisms may alter dietary selenium and metabolize it differently than they do sulphur. Notwithstanding this fact, sulphur easily substitutes for selenium in the biological system and is known to interfere with the metabolic functions of selenium (Sutmoller, 1972b; Whanger, 1970). On the other hand, both Whanger (1970) and Allaway (1970) mention cases where there is little if any inhibitory effect from sulphur.

Whanger makes an important point in relation to the discrepancy of results from several studies where the interaction of sulphate and selenium have been investigated. Apparently the fate of selenium metabolism depends upon the level of sulphur in the diet: in a study on the effect of 0.05, 0.10, 0.15, and 0.20% total sulphur in the diet, the selenium metabolism for the low sulphur level (0.05%) was different from that for the higher percentages. This level is below that of sulphur usually found in animal forage (0.1-0.2%).

A conclusion stated in Allaway's paper (1970) is that when areas are low in selenium and require fertilization for good crop yield, fertilization should be undertaken and preventative measures should be taken for WMD. This is a recommended procedure for the situation in Alberta, as the workers interviewed agreed that this would be an effective way to control WMD.

6. SELENIUM-CANCER RELATIONSHIP

Selenium has been classified as a carcinogen, resulting in its prohibition as a feed additive. As there is considerable controversy on this point, it will be worthwhile to describe the situation; more detail may be found in the paper by Frost (1971).

In 1943 the U.S. Food and Drug Administration (USFDA) reported (Nelson *et al.*, 1943) that rats developed cirrhosis when fed chronically toxic levels of potassium ammonium sulfoselenide, the first systemic insecticide. After 18 months, during which time most of the test rats had cirrhosis, some tumors grew out of the cirrhotic livers. In 1958, selenium was banned as a feed additive under the Food Additive Law, the basis being this 1943 report, although a subsequent paper (Fitzhugh *et al.*, 1944) stated that none of the tumors became malignant. It should be noted that it was

not until 1957 that selenium was discovered to be essential to health. A letter sent by Schroeder (1970) to the USFDA stated that he had produced cancerous tumors by feeding 3 parts per million sodium selenate in water to rats.

In contrast to these two studies and a third in Russia, the literature contains a large number of studies which show the salutary nature of selenium and in fact some investigators indicate that selenium can prevent or inhibit carcinogenesis under certain conditions. Toxicity occurs only when selenium intake exceeds excretory capacity, which is at least ten times the requirement for most species tested.

Considerable effort is currently underway to remove the controversy. Both the USFDA and the Canada Department of Agriculture (CDA) are attempting to establish a case for selenium as a feed additive. The proposed level is 0.1 part per million for chickens and swine, 0.2 part per million for turkeys. Needless to say there is sufficient evidence available at present to clear selenium as a feed additive or mineral supplement in salt licks for cattle on other than a prescription basis.

7. THE ALBERTA SCENE

Although cases of WMD have been diagnosed in livestock in most parts of Alberta, the potential total incidence of the disease is unknown. The same can be said for Mulberry Heart Disease in swine. Sutmoller (1972) indicated at Public Hearings that about 5% of his case load consisted of diagnosed cases of WMD and it is understood most farmers in the Innisfail area are using a selenium dietary supplement. Without selenium supplements the livestock industry in central Alberta would be in serious jeopardy.

The Animal Diseases Section of the Laboratory Services Branch, Alberta Department of Agriculture, has been in existence for several years, and was established to diagnose diseases in animals sent to it by veterinarians and farmers; no research is undertaken. As the only source of province-wide information, the Section diagnosed 50 cases of WMD in cattle in 1965; in 1971 the number was 118. In 1971 there were 34 reported cases of Mulberry Heart Disease in swine. However, these cases represent only a fraction of the total, as local veterinarians see and diagnose the vast majority of animals without the necessity of submitting the details of their case load to any on-going province-wide information centre. This is an unfortunate oversight.

It should be noted that the distribution in cases of WMD diagnosed by the provincial laboratory follows very closely the variation in selenium levels with soil zone as indicated in Table 2: the highest incidence is in zone 8, a Grey Wooded soil yielding a high percentage of selenium-deficient forage. This is an area of intensive cultivation in contrast to other grey soil regions of Alberta.

There is one question as to the best method of supplying nutritional selenium dosages to livestock, especially because of the varying levels which exist in forage. Certainly for swine and poultry, which usually have commercial feeds as their only source of food, the addition of selenium to the feed should be an adequate preventative measure, provided strict control was exercised over its incorporation into the feeds. For cattle this method may not prove to be satisfactory, as feeds can be prepared on a local level at mills where the personnel are not knowledgeable about nutritional needs; in addition, cattle are let out to pasture to feed on local vegetation. Veterinarians are more familiar with the health aspects of treatment or preventative measures and they would be more capable of supplying the correct quantities of supplement. The preferred method is to supply the selenium as a mineral supplement in salt licks as this allows the dosage to be prepared on an individual basis. If a more extensive forage testing program were set up by the Department of Agriculture, with the results being forwarded to the local veterinarian, then it is expected that occurrences of WMD and related diseases would be greatly reduced.

8. SULPHUR IN THE ENVIRONMENT AND ITS RELATION TO EMISSIONS FROM SOUR GAS PROCESSING PLANTS

8.1 Historical

The west central portion of Alberta, wherein the greatest concentration of sour gas processing plants is to be found, is predominantly of two basic soil types: Grey Wooded soil and Black soil. Grey Wooded soils are low in natural fertility and respond to the application of mineral fertilizers, especially sulphur as sulphate, and additions of organic matter. Careful soil management is required to achieve good productivity from such soils. Black soils, in contrast, are generally of high productivity.

In the area in question Grey Wooded soils predominate. Such soils additionally constitute over one-half of the currently cultivated plus potentially arable land of the province. During the last five years, visible symptoms of sulphur deficiency have appeared in Black soil zones as well. This is not surprising in view of the many years of net sulphur removal by crops. Sulphur deficiency is usually associated with soils having good drainage, coarse texture, and a relatively low content of organic matter.

As a result of much experimentation with a variety of soil management programs carried out under the guidance of Dr. C.F. Bentley of the University of Alberta, Department of Agriculture, substantially increased forage and grain crop yields have been realized from the soils in question, thereby making sulphur-deficient soils of west central Alberta equal in productivity to much of the most fertile land in the province. As a consequence of increased forage yields livestock have assumed a greater proportion of farm income generated in this area over the past ten years.

Concurrent with these developments, beginning in the early 1960's, increased incidence of White Muscle Disease (WMD) and general unthriftiness in cattle and hogs was diagnosed in many areas of the province, but principally in the region south of Edmonton, north of Calgary and west of Highway No. 2 to the edge of the cultivated area. The above mentioned debilitations respond favourably to injections of selenium (as sodium selenite) and vitamin E. The importance of selenium deficiency in feeds as one of the factors contributing to some muscle degeneration diseases has been well documented; suggested minimum requirements are 30-200 parts per billion total selenium in the daily feed ration.

8.2 The Affected Farmer

Many farmers in west central Alberta are presently opposed to further sulphate fertilization on the grounds that where this has been practiced, increased incidence of WMD has resulted. It has further been assumed by many farmers in the same area that increasing emissions of sulphur dioxide from sour gas processing plants and their attendant batteries already contribute sufficient sulphur to the soil to preclude the need for further sulphate additions (Sutmoller, 1972). In this way, then, many farmers and a few veterinarians believe there may be a correlation between gas plant emissions and the increased diagnosis of WMD, especially in areas where sour gas plants are located.

The question to consider then is the relationship between the application of sulphur, either applied in known amounts in a fertilizer or deposited from sour gas plant emissions, and a decrease in the selenium content of vegetation. It has been experimentally shown (Davies and Watkinson, 1966; Walker, 1971) that selenium concentration decreases when plant growth is stimulated by sulphate fertilization (see Section 1.2). Although the literature references attribute the selenium concentration decrease principally to dilution, i.e., a relatively constant selenium uptake by the forage, the increased sulphur available to the plant should also inhibit the selenium uptake. This is to be expected from the relative chemical similarity of the two elements and their ease of exchange in chemical processes.

9. SULPHUR FROM SOUR GAS PLANT EMISSIONS

9.1 Sulphur in Precipitation

Do the emissions from sour gas processing plants (see Figure 1 for locations of these plants) and their ancillary facilities contribute sufficient sulphur to relieve the natural sulphur deficiency of the soils in west central Alberta? From sulphate analyses of both snow and rainfall from 60 sites within a 3,600 square mile area (35 mile radius) of west central Alberta, Walker (1969) estimated 2-4 lbs. sulphur/acre/year as sulphate is brought down in precipitation. No doubt some of this is lost as a result of surface run-off. A later independent study by Summers and Hitchon (1971) of the entire area between Edmonton and Calgary west of Highway No. 2, substantiates Walker's results and further suggests that during the winter only a small fraction of sulphur dioxide emitted to the atmosphere is brought to earth as sulphate incorporated in snowfall. The ultimate fate of sulphur dioxide emitted during the winter should be an important matter for further study, although the matter is apparently not immediately relevant to the selenium issue.

Taking into account sulphate added to the soil by precipitation Walker concluded (1969, 1971b) from five field test plots that 1970 levels of sulphur oxides in the atmosphere over west central Alberta seemed to be contributing insufficient sulphur to the soil to eliminate the sulphur deficiency which

existed, except where such deficiency was marginal. Farmers operating close to sour gas plants would tend to dispute this conclusion, however.

9.2 Absorption of Sulphur Dioxide by Soil and Vegetation

Direct absorption of sulphur dioxide by the soil and by green plant surfaces is also a source of sulphur for vegetation. The most comprehensive study on soil absorption was done in Sweden by Johansson (1959) whose results indicated direct absorption contributed considerably more sulphur dioxide to the exposed soil than did sulphate sulphur in precipitation. It would only be by integrating data from individual mobile monitors that the Swedish results might be applied to Alberta conditions in even a general manner. However, Walker concluded in his studies that direct soil absorption was not an important source for sulphur. He did not discuss direct gas absorption by the plant.

Sulphur dioxide absorption by the plant itself is a controversial issue in that it may be thought of as a beneficial aid to plant growth on the one hand and as a harmful pollutant on the other. It is not necessary to enter into a discussion of the harmful effects of sulphur dioxide on vegetation as this is well documented elsewhere. What is important to note is that there exists a threshold level (not necessarily static) above which damage can be observed in the plant; below this threshold level the absorbed sulphur dioxide <u>may</u> be considered as a plant nutrient. In general, crop yields are not affected unless approximately five percent of the leaf area has been destroyed; for alfalfa, leaf destruction can be approximately five percent without decreasing total yield, even after several fumigations.

When sulphur dioxide is present in the atmosphere below a level which is assumed not to inflict plant damage, it is often considered to be a plant nutrient, as it can be assimilated into the plant by oxidation through sulphur to sulphate. In fact, it has been found (Katz, 1949) that fumigation of alfalfa with sulphur dioxide concentrations below 0.2 ppm caused no harm, and he suggested that concentrations between 0.1 and 0.2 ppm are beneficial especially on plants prone to sulphur deficiency. This is also the belief of the sour gas industry, as stated in the Canadian Petroleum Association submission to the Public Hearings regarding overall sulphur deposition: "...in the growing season the sulphur emissions from Alberta gas plants are deposited within Alberta and utilized by crop vegetation." We do not know of research carried out in Alberta to prove the beneficial effects of sulphur dioxide emissions.

Plants vary in their sensitivity to sulphur dioxide (or any pollutant) and even an individual species will have a variable sensitivity depending on numerous factors; for example a plant is usually most susceptible to damage in its growing stage. Among the most sensitive species are the forage crops, alfalfa and barley; they are followed closely by rye, oats, clover and wheat; the most sensitive forest species are trembling aspen and jack pine. There is evidence from scientific studies in Alberta that trembling aspen in various parts of the province have exhibited mild sulphur dioxide stress but this has not been shown to have seriously affected this species. Although no evidence has been produced to indicate any sulphur dioxide damage to forage and cereal crops, the fact that they are as sensitive as and maybe more sensitive than the forest species would indicate that these crops may also have been subjected to some stress. These stresses are very often not prominent, but may require examination by an expert to detect, and therefore, given all the variables of crop production, may go unnoticed.

Assuming that low levels of sulphur dioxide are present in the atmosphere much of the time in central Alberta, vegetation can be expected to absorb some of this gas. Under normal conditions this sulphur dioxide may be a nutrient, and in this respect will promote plant growth; it is expected that once the plant oxidizes the sulphur dioxide to sulphate, it would act as a fertilizer. Walker's studies do not indicate that the sulphur dioxide in the air contributed to growth (of course, in relation to this, he did not have test plots that were exposed to pure air for comparison purposes).

9.3 Hydrogen Sulphide

Hydrogen sulphide may be another source of sulphur, but the gas plant operations in effect reduce its emission into the atmosphere to much less than that of sulphur dioxide. All sour gases from which sulphur is recovered are burnt in a furnace to convert hydrogen sulphide and other sulphur compounds to sulphur dioxide before emission to the atmosphere. There may be small amounts of hydrogen sulphide released from flares, but this is not expected to be detrimental to vegetation. Hydrogen sulphide is less harmful to vegetation than is sulphur dioxide at equivalent levels; under normal circumstances, hydrogen sulphide is not expected to contribute to any large extent to beneficial or detrimental effects on vegetation.

9.4 Research

The field plots in Walker's investigation were not less than seven miles from the Homeglen-Rimbey sulphur extraction plant. It is unfortunate that test plots were not situated in closer proximity to the gas plant, especially since the information available indicates that farmers relatively close to the gas plants have been under the impression that atmospheric sulphur being deposited is sufficient for crop growth and in many cases aggravates WMD. There may be merit in testing for total sulphur deposition on plots closer to a plant, based on the following points: a) sulphur in precipitation appears to increase nearer the plant; b) Johansson's data indicate that more sulphur is absorbed from the atmosphere than deposited by precipitation; c) stack calculation equations indicate that maximum concentration of a stack plume near ground level would normally occur between ten and twenty stack heights downwind: for a 400 foot stack this would be about one to two miles. The published data for Alberta relate only to the Homeglen-Rimbey gas plant which exhausts approximately 20 tons of sulphur (as sulphur dioxide) per day; if deposition is dependent on stack emission then more sulphur may be added to the soil near larger plants.

10. FERTILIZATION

Since a large portion of soils are normally sulphur deficient, if sulphur was not contributed by emanation from sour gas processing plants, sulphate fertilizer would have to be added by the farmer to obtain maximum crop growth. However, without regular soil analyses by the Department of Agriculture, local inhabitants find it difficult to ascertain what fraction of their total sulphur requirement has been met by fallout from local sour gas plants or natural soil sulphur and therefore how much additional fertilizer must be applied. Certainly at this time the value of increased crops to be derived from adequate applications of sulphur outweighs the present cost of preventing the occurrence of WMD by adding selenium to salt licks. Even when fertilization is not carried out, there will be a possibility of WMD occurring due to the potential selenium-deficient nature of many soils.

11. CONCLUSIONS

11.1 White Muscle Disease and its Treatment

There is little doubt that diagnosis of White Muscle Disease has become more frequent over the past few years; incidence of the disease is particularly acute in west central Alberta. Analysis of forage crops for selenium content indicates that there is a geographical variation which closely follows the soil zones. An extensive soil management program primarily based on sulphate sulphur fertilization has converted the Grey Wooded soil of west central Alberta into one of the most productive in the entire province. Such a policy of fertilization has aggravated the natural selenium deficiency by decreasing the already low levels of selenium in vegetation. It should not be inferred that selenium deficiency in animals would not occur without sulphur fertilization.

All evidence indicates that the major cause of the incidence of WMD is the intensive agricultural use of land that is marginal in soluble selenium. More extensive grazing by larger herds and a greater awareness by veterinarians of disease symptoms also contribute to the total reported cases. Fortunately, the diseases discussed in this paper can be controlled, although they cannot be eliminated. The easiest means of prevention, and that recommended by veterinarians, is to supplement the salt diet of cattle with selenium-vitamin E on a prescription basis; known cases of WMD can be treated individually with injections. At present the Canada Department of Agriculture is in the process of clearing selenium as a feed additive for swine and poultry and expects to do the same in the future for cattle feed. It would appear that several practising veterinarians are opposed to the addition of selenium to feeds.

11.2 Selenium-Responsive Diseases, Fertilizers and Sour Gas Plants

While it can be stated that soil characteristics are the predominant factor causing less than nutritional levels of selenium in forage crops, any growth stimulant may be expected to decrease the selenium content. It does not matter whether one talks of a "dilution" effect, (a relatively constant selenium uptake as yield is increased), or a sulphur (from the nutrient additive) substituting for selenium--the result is a lower selenium concentration in either case. As indicated by Walker's data in Table 1,

any livestock fed a diet of forage (other than mostly alfalfa) in this category would likely exhibit symptoms of WMD, whether or not the crop had been fertilized. Therefore, it is to be expected that WMD may occur even when farmers do not fertilize their land, especially where the soil is low in soluble selenium.

The location of the majority of sour gas plants in central Alberta appears to be fortuitous in that the Grey Wooded soils in this area are known to be deficient in soluble selenium (from the standpoint of animal nutrition). It could be said that, within limits, sulphur deposited as a result of gas plant emissions is beneficial in stimulating plant growth; however these emissions have been pointed out as the cause of WMD. Many farmers to not fertilize because they believe this increases the incidence of WMD (Sutmoller, 1972; Walker, 1971a) or that gas plants add sulphur to the soil and thereby caused WMD. In fact it has been stated that two or three years after a gas plant near Innisfail began operation, there was an increase in selenium-responsive diseases near the plant. The discrepancy between the experimental data and the beliefs of farmers and veterinarians appears to be related to the distance from the gas plant; unfortunately the only scientific data has been obtained at a minimum distance of seven miles from the nearest gas plant.

In this respect we do not have sufficient evidence to actually state that gas plants have affected crop growth or have been contributory to the increased incidence of White Muscle Disease. All of the following have increased over the past several years: gas plant emissions, use of sulphate fertilizer, marginal land being brought into production, livestock grazing, knowledge of WMD and its diagnosis. The exact role played by each is not fully known and the necessary information is not presently available to determine each role. Judging from what is known, however, we do not believe sour gas plants can be held responsible for the general increased incidence of WMD. This does not dismiss the possibility that sulphur deposition may in some instances be sufficient as to stimulate vegetation growth, but even in these cases other factors will also contribute to modifying selenium intake.

11.3 Atmospheric Sulphur Deposition

From the work of Summers (1971) and Walker (1969, 1971b) the amount of sulphur added to the soil (for the district in west central Alberta

near the Homeglen-Rimbey gas plant) in precipitation is estimated between 2 and 4 lbs./acre. Walker concludes that the soil is insufficient to affect plant growth, as sulphur fertilization produced significant increases in yield. From an economic point of view, it would be beneficial to know the extent of sulphur deposition or soil content so as to prevent this addition of excess fertilizer by the farmer.

The beneficial effect of atmospheric deposition of sulphur to the soil must, however, be viewed in the context of the total environmental situation with respect to gas plant emissions. It must be remembered that from the time sulphur dioxide leaves the plant until it is returned to the soil, it can affect vegetation and the health of humans and animals. At the Public Hearings, evidence was given to indicate that in certain areas, slight vegetational stress due to sulphur dioxide had occurred and several individuals had stated that their health had been impaired by gas plant emissions; unfortunately scientific evidence for the health aspects was lacking. In addition, sulphate deposited and not removed in crop production may lead to soil acidification over a long period of time.

The main conclusion of our report is that the incidence of White Muscle Disease is a direct result of soil characteristics. Gas plants are emitting sulphur which returns to the ground, but unless the total return is much greater than precipitation data would suggest, this sulphur is essentially supplementing the natural soil sulphur and that applied as fertilizer. If the total atmospheric deposition was known, then in some cases the farmer might obtain sufficient crop yield without adding fertilizer. As long as it is understood that WMD and other selenium-responsive diseases will occur in areas that are marginal in soil selenium, or where the low levels of selenium are affected by sulphur fertilization or sulphur from gas plants, preventative steps for WMD can be taken. Proper farm management will increase the crop yield and prevent the occurrence of WMD.

These statements should not be construed as an endorsement of crop fertilization by atmospheric sulphur sources, as we believe this to be an unsound environmental practice. However, as the gas plants are in existence, and emissions from them cannot be eliminated, then the overall effects of these emissions must be determined, whether they are effects on plants, animals or humans.

12. RECOMMENDATIONS

On the basis of our investigation we do not believe that there is a requirement for direct research into selenium-responsive diseases, as extensive work is being done in other countries. It is known that unless preventative measures are taken, WMD and other symptoms of selenium deficiency will occur as a direct result of soil conditions in Alberta. Of utmost importance to the farming community is good crop management and a healthy herd; application of known amounts of fertilizer and supplementing diets with selenium additives (or other necessary nutrients) should ensure this. What is not known is how much sulphur is being added to the soil by gas plants, especially close to the plants, and how this will affect the quantity of the fertilizer the farmer must add for maximum crop yield.

The following recommendations are concerned with the present situation regarding relationships among government, veterinarians, and farmers:

1. A more extensive record of veterinarian activities should be kept by the provincial Department of Agriculture; we found it difficult to obtain information on the extent of WMD, as the Veterinary Services Division had records of only those animals they received for examination.

2. There should be an increased dialogue between the federal and provincial departments and practising veterinarians concerning the best way to prevent WMD. Addition of selenium to feeds, especially to cattle feed, may not meet with universal approval if, as veterinarians believe, mineral supplements on prescription allow them more control in alleviating selenium deficiency.

3. We agree with the Department of Agriculture that fertilizer should be added to soils and preventative measures taken for selenium deficiency. Monitoring of forage for selenium and of soils for sulphur should be an on-going program. Only by knowing actual deposition quantities of sulphur or selenium content of vegetation can the Department of Agriculture advise the farmers on proper management.

4. Government should be more responsive to the concerns of the farming community and attempt to allay the fears of its members. Many farmers do not fertilize because they believe enough sulphur is being added by gas plants, or that combination of fertilizer and gas plant emissions contribute to a selenium deficiency. An educational and informational program to outline what is known and suggest management practices would be most beneficial in this case.

This investigation has revealed a number of inconsistencies in our knowledge about gas plant emissions. While this may be peripheral to the central focus of this report on selenium (in fact, we view the case of selenium as only one segment of the emission question), we feel that some recommendations should be made here because of the importance of the issue:

1. A research should be undertaken to determine the radial distribution of sulphur deposited by gas plant emissions. There is a need to study depositions close to plants than the seven miles as reported by Walker, as much concern centres around the farming communities near gas plants. Studies that are presently being carried out by the gas industry may supply much of this necessary data. Complementing this program should be an analysis for selenium in vegetation.

2. An opportunity exists to determine future sulphur buildup in soils where new gas plants have been built. Knowledge of this sort is important if the long-term effects of sulphur deposition are to be evaluated. For example, a detrimental progressive increase in soil acidity has been postulated.

3. Total sulphation cylinders are situated immediately around gas plants. Apparently, the data obtained from these cylinders are not easily related to ambient air concentrations, nor have they been used to determine the fate of emissions, be it absorption by vegetation or soil, or removal

in precipitation. We recommend that research be undertaken to establish if a relationship between cylinder data and the various rates of emissions does exist.

4. Before new sour gas plants are constructed, it is recommended that the total environment be monitored for all the variables that are presently of concern. In the past the physical environment may have been monitored; we also believe it is important to have a knowledge of the social environment: the health and welfare of humans and other animals.

A list of references specific to the subject matter of this chapter is included at the end of this report.

TABLE 1 SELENIUM IN TOP GROWTH IN FORAGE SPECIES (*)

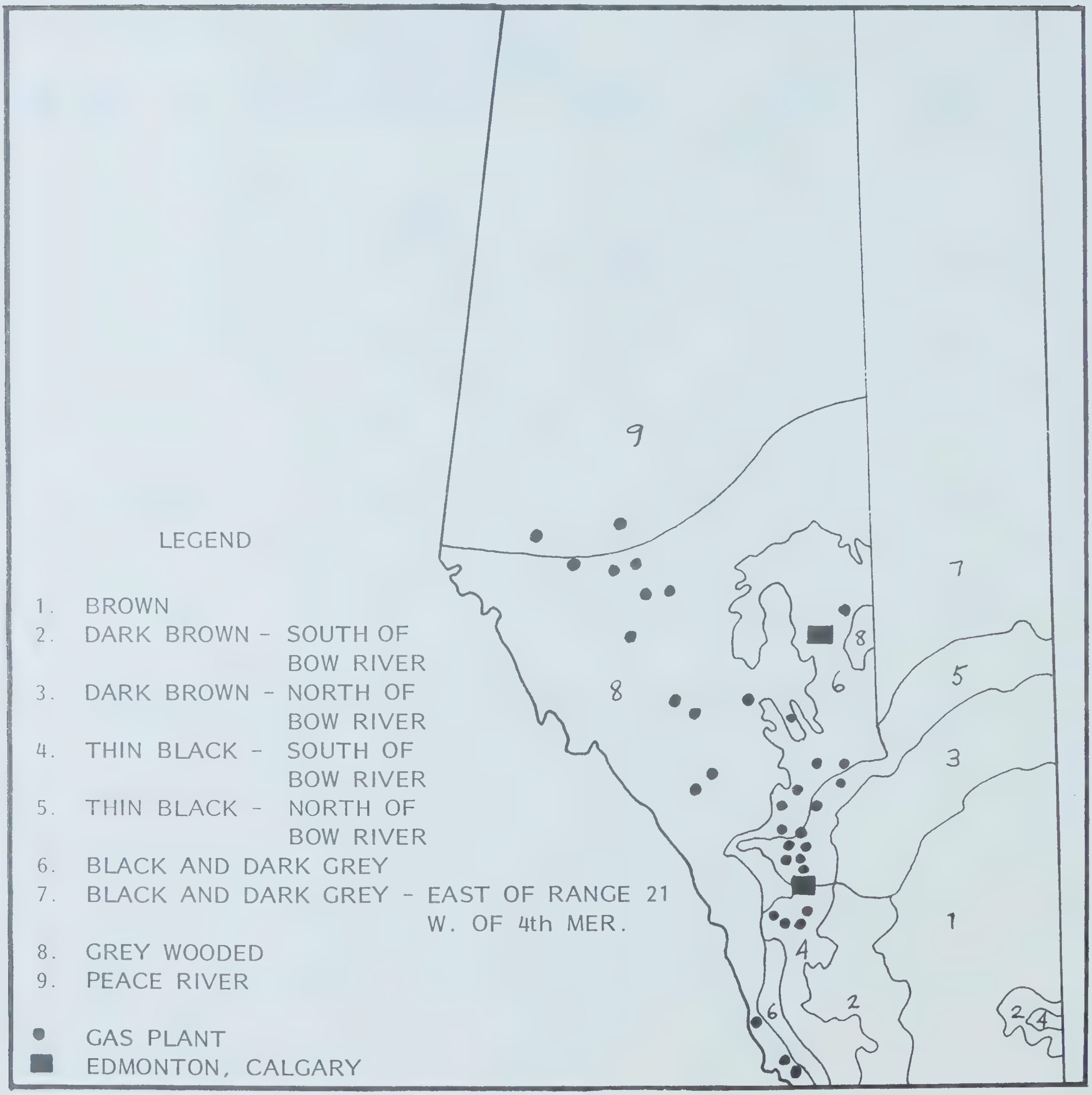
Species	Yield Response to S fertilizer	No. of samples	Ave. Se in top growth (ppb)	
			Without S fertilizer	With S fertilizer
alfalfa	yes	10	242	112.3
	no	13	112.5	78.5
alsike clover	yes	31	18	12.9
	no	7	24	14.7
red clover	yes	26	18.5	11.1
	no	4	8	6.5
bromegrass	yes	7	27.7	21.6
	no	8	30.8	26.4
timothy	yes	19	12	10.6
	no	6	11.7	9.0

(*) From Walker, D.R., *Can. J. Soil Sci.* 51, 506 (1971)

TABLE 2 SELENIUM LEVELS IN BARLEY GRAIN

Soil Area	No. of Samples	Percent of Samples Tested			
		100 ppb	100-199 ppb	200-1000 ppb	1000 ppb
1	24	16.7	12.5	62.5	8.3
2	33	18.2	9.1	66.7	6.1
3	44	11.4	25.0	59.0	4.5
4	21	19.0	28.6	52.4	-
5	68	23.5	42.6	33.8	-
6	109	71.5	16.5	11.0	0.9
7	31	51.6	45.2	3.2	-
8	30	80.00	16.7	3.3	-
9	34	64.7	17.6	17.6	-

FIGURE 1. SOIL ZONES AND SULPHUR EXTRACTION GAS PLANTS IN ALBERTA



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